Tom Petty Problems (g=9.81m/s²)

1) If a rock takes 0.750 s to hit the ground after being thrown down from a height of 4.80 m, determine the rock's initial velocity. [2.72 m/s [down]]

$\Delta t = 0.750\text{ s}$
$\Delta \vec{d} = -4.80\text{ m}$
$\vec{a} = \vec{g} = -9.81\text{ m/s}^2$
$\vec{v}_1 = ?$

$\Delta \vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$\frac{\Delta \vec{d} - \frac{1}{2}\vec{a}(\Delta t)^2}{\Delta t} = \vec{v}_1$

$\vec{v}_1 = \frac{-4.80\text{ m} - \frac{1}{2}(-9.81\text{ m/s}^2)(0.750\text{ s})^2}{0.750\text{ s}}$

$\vec{v}_1 = -2.725\text{ m/s}$

2) Having scored a touchdown, a football player spikes the ball in the end zone. If the ball was thrown down with an initial velocity of 2.0 m/s from a height of 1.75 m, determine how long it is in the air. [0.43 s]

$\vec{v}_1 = -2.0\text{ m/s}$
$\Delta \vec{d} = -1.75\text{ m}$
$\vec{a} = \vec{g} = -9.81\text{ m/s}^2$
$\Delta t = ?$

$\Delta \vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$
$-1.75\text{ m} = -2.0\text{ m/s}\,\Delta t + \frac{1}{2}(-9.81\text{ m/s}^2)(\Delta t)^2$
$0 = 1.75\text{ m} - 2.0\text{ m/s}\,\Delta t - 4.905\text{ m/s}^2(\Delta t)^2$

Quadratic:
$\frac{2.0 \pm \sqrt{(-2.0)^2 - 4(-4.905)(1.75)}}{2(-4.905)}$

$\Delta t = 0.43\text{ s}$

$\Delta t = 0.83\text{ s}$ or 0.43 s

Alternate:
① Find $\vec{v}_2$
② Then find Δt

3) An elevator moving downward at 4.00 m/s experiences an upward acceleration of 2.00 m/s² for 1.80 s. What is its velocity at the end of the acceleration and how far has it travelled? [0.400 m/s [down], 3.96 m]

$\vec{v}_1 = -4.00\text{ m/s}$
$\vec{a} = 2.00\text{ m/s}^2$
$\Delta t = 1.80\text{ s}$
$\vec{v}_2 = ?$
$\Delta \vec{d} = ?$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$
$\vec{v}_2 = -4.00\text{ m/s} + (2.00\text{ m/s}^2)(1.80\text{ s})$
$\vec{v}_2 = -0.400\text{ m/s}$

$\Delta \vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$
$\Delta \vec{d} = -4.00\text{ m/s}(1.80\text{ s}) + \frac{1}{2}(2.00\text{ m/s}^2)(1.80\text{ s})^2$
$\Delta \vec{d} = -3.96\text{ m}$
$\Delta d = 3.96\text{ m [down]}$

4) A clown throws a ball upward at 10.00 m/s. Find

(a) the maximum height the ball reaches above its launch height. [5.10 m]

$\vec{v}_1 = 10.00\text{ m/s}$
$\vec{v}_2 = 0\text{ m/s}$
$\vec{a} = -9.81\text{ m/s}^2$
$\Delta \vec{d} = ?$

$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta \vec{d}$
$\frac{-\vec{v}_1^{\,2}}{2\vec{a}} = \Delta \vec{d}$
$\Delta \vec{d} = \frac{-(10.00\text{ m/s})^2}{2(-9.81\text{ m/s}^2)}$
$\Delta \vec{d} = 5.10\text{ m}$

(b) the time it takes to do so. [1.02 s]

$\Delta t = ?$

$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$
$\Delta t = \frac{\Delta \vec{v}}{\vec{a}}$
$\Delta t = \frac{0 - 10.00\text{ m/s}}{-9.81\text{ m/s}^2}$
$\Delta t = 1.019368\text{ s}$
$\Delta t \approx 1.02\text{ s}$

(c) the time it takes the ball to return to the clown's hand from maximum height. [1.02 s]

$\Delta \vec{d} = -5.10\text{ m}$
$v_y = 0\text{ m/s}$
$a = -9.81\text{ m/s}^2$

$\Delta \vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$
$\sqrt{\frac{2\Delta \vec{d}}{\vec{a}}} = \Delta t$
$\Delta t = \sqrt{\frac{2(-5.10\text{ m})}{-9.81\text{ m/s}^2}}$
$\Delta t = 1.02\text{ s}$

(d) the ball's final velocity. [-10.0 m /s]

$\Delta t = 1.02\,s$
$\Delta \vec{d} = -5.10\,m$
$\vec{v}_1 = 0\,m/s$
$a = -9.81\,m/s^2$
$\vec{v}_2 = ?$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

$\vec{v}_2 = \vec{a}\Delta t$

$\vec{v}_2 = -9.81\,m/s^2(1.02\,s)$

$\vec{v}_2 = -10.0\,m/s$

5) The Slingshot drops riders 27 m from rest before slowing them down to a stop. How fast are they moving before they start slowing down? [23 m/s]

$\Delta \vec{d} = -27\,m$
$\vec{v}_1 = 0\,m/s$
$\vec{v}_2 = ?$
$\vec{a} = -9.81\,m/s^2$

$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$

$\vec{v}_2 = \pm\sqrt{2\vec{a}\Delta\vec{d}}$

$\vec{v}_2 = \pm\sqrt{2(-9.81\,m/s^2)(-27\,m)}$

$\vec{v}_2 = \pm 23\,m/s$

$\vec{v}_2 = -23\,m/s$

6) A pebble falls from a ledge 20.0 m high.

(a) Find the velocity with which it hits the ground. [19.8 m/s [down]]

$\Delta \vec{d} = -20.0\,m$
$\vec{v}_1 = 0\,m/s$
$\vec{v}_2 = ?$
$\vec{a} = -9.81\,m/s^2$

$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$

$\vec{v}_2 = \pm\sqrt{2\vec{a}\Delta\vec{d}}$

$\vec{v}_2 = \pm\sqrt{2(-9.81\,m/s^2)(-20.0\,m)}$

$\vec{v}_2 = \pm 19.8\,m/s$

$\vec{v}_2 = -19.8\,m/s$

(b) Find the time it takes to hit the ground. [2.02 s]

$\Delta t = ?$

$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$

$\Delta t = \frac{\Delta\vec{v}}{\vec{a}}$

$\Delta t = \frac{-19.8\,m/s - 0\,m/s}{-9.81\,m/s^2}$

$\Delta t = 2.02\,s$

7) Why does it make sense that the time taken to travel up to the maximum height is equal to the time to fall back down to the starting height?

- cover the same distance with the same acceleration

8) What variables determine how long a projectile is in the air? Does the answer surprise you? Why or why not?

9) What should be the value of the slope of the velocity-time graph for vertical projectile motion?

$-9.81\,m/s^2$ (acceleration due to gravity)

10) What determines how long it will take an object to reach the ground when released with an initial velocity of zero?

-the height it is dropped from

11) A student drops a bran muffin from the roof of the school. From what height is the muffin dropped if it hits the ground 3.838 s later? [72.3 m]

$\Delta d = ?$
$\Delta t = 3.838\ s$
$\vec{v}_1 = 0\ m/s$
$\vec{a} = -9.81\ m/s^2$

$\Delta\vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = \frac{1}{2}(-9.81\ m/s^2)(3.838\ s)^2$

$\Delta\vec{d} = -72.2518\ m$

∴ Dropped from a height of 72.3 m

12) A rock takes 1.575 s to drop 2.00 m down toward the surface of the Moon. Determine the acceleration due to gravity on the Moon. [1.61 m/s^2 [down]]

$\Delta t = 1.575\ s$
$\Delta\vec{d} = -2.00\ m$
$\vec{a} = ?$
$\vec{v}_1 = 0\ m/s$

$\Delta\vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = \frac{1}{2}\vec{a}(\Delta t)^2$

$\frac{2\Delta\vec{d}}{(\Delta t)^2} = \vec{a}$

$\vec{a} = \frac{2(-2.00\ m)}{(1.575\ s)^2}$

$\vec{a} = -1.61\ m/s^2$

13) At the beginning of a game, a referee throws a basketball vertically upward with an initial speed of 5.0 m/s. Determine the maximum height above the floor reached by the basketball if it starts from a height of 1.50 m. [2.8 m]

$\vec{v}_1 = 5.0\ m/s$
$\Delta\vec{d} = ?$
$\vec{v}_2 = 0\ m/s$
$\vec{a} = -9.81\ m/s^2$

$\vec{v}_2^2 = \vec{v}_1^2 + 2\vec{a}\Delta\vec{d}$

$\frac{-\vec{v}_1^2}{2\vec{a}} = \Delta\vec{d}$

$\Delta\vec{d} = \frac{-(5.0\ m/s)^2}{2(-9.81\ m/s^2)}$

$\Delta\vec{d} = 1.3\ m$

$\Delta d = 1.3\ m + 1.5\ m$

$\Delta d = 2.8\ m$

14) If the acceleration due to gravity on Jupiter is 24.8 m/s2 [down], determine the time it takes for a tennis ball to fall 1.75 m from rest. [0.376 s]

$\vec{g} = -24.8\ m/s^2$
$\Delta\vec{d} = -1.75\ m$
$\vec{v}_1 = 0\ m/s$
$\Delta t = ?$

$\Delta\vec{d} = \vec{v}_1 \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = \frac{1}{2}\vec{a}(\Delta t)^2$

$\frac{2\Delta\vec{d}}{\vec{a}} = \Delta t$

$\Delta t = \pm\sqrt{\frac{2(-1.75\ m)}{-24.8\ m/s^2}}$

$\Delta t = \pm 0.37567\ s$

$\Delta t \approx 0.376\ s$

15) If a baseball popped straight up into the air has a hang time (length of time in the air) of 6.25 s, determine the distance from the point of contact to the baseball's maximum height. [47.9 m]

$\Delta t_{up} = \frac{6.25\ s}{2} = 3.125\ s$
$\Delta d = ?$
$\vec{a} = -9.81\ m/s^2$
$\vec{v}_2 = 0\ m/s$

$\Delta\vec{d} = \vec{v}_2 \Delta t - \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = -\frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = -\frac{1}{2}(-9.81\ m/s^2)(3.125\ s)^2$

$\Delta\vec{d} \approx 47.9\ m$

16) A person in an apartment building is 5.0 m above a person walking below. She plans to drop some keys to him. He is currently walking directly toward a point below her at 2.75 m/s. How far away is he if he catches the keys 1.25 m above the ground? [2.4 m]

17) A rocket launched vertically upward accelerates uniformly for 50 s until it reaches a velocity of 200 m/s [up]. At that instant, its fuel runs out.

(a) Calculate the rocket's acceleration. [4.0 m/s^2 [up]]

$\vec{v}_1 = 0\ m/s$
$\vec{v}_2 = 200\ m/s$
$\Delta t = 50\ s$
$\vec{a} = ?$

$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ $\quad \vec{a} = \frac{200\ m/s - 0\ m/s}{50\ s}$

$\vec{a} = 4\ m/s$

(b) Calculate the height of the rocket when its fuel runs out. [5.0 x 10^3 m]

$\Delta \vec{d} = ?$

$\Delta \vec{d} = \frac{1}{2}(\vec{v}_2 + \vec{v}_1)\Delta t$

$\Delta \vec{d} = \frac{1}{2}(200\ m/s + 0\ m/s)(50\ s)$

$\Delta \vec{d} = 5000\ m$

$\Delta \vec{d} = 5 \times 10^3\ m$

(c) Explain why the rocket continues to gain height for 20 s after its fuel runs out.

When fuel runs out, it still has an upwards velocity
It will take about 20 s to come to a stop because of gravity
(could show mathematically)

(d) Calculate the maximum height of the rocket. [7.0 x 10^3 m]

$\Delta d_{max} = \Delta d_{fuel} + \Delta d_{drop}$

$\Delta d_{fuel} = 5.0 \times 10^3\ m$

$\vec{v}_2 = 0\ m/s$
$\vec{v}_1 = 200\ m/s$
$\vec{a} = -9.81\ m/s^2$

$v_2^2 = v_1^2 + 2\vec{a}\Delta\vec{d}$

$\frac{-v_1^2}{2\vec{a}} = \Delta d$

$\Delta d_{drop} = \frac{-(200\ m/s)^2}{2(-9.81\ m/s^2)}$

$\Delta d_{drop} \approx 2039\ m$

$\Delta d_{max} = 5.0 \times 10^3\ m + 2039\ m$

$\Delta d_{max} \approx 7039\ m$

$\Delta d_{max} \approx 7.0 \times 10^3\ m$